（ 続紙 1 ）

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論文題目	Detailed analysis of the transverse arch of hallux valgus feet with and without pain using weight-bearing ultrasound imaging and precise force sensors (荷重時の超音波画像と力センサーによる痛みの有無による外反母趾足の横アーチの詳細分析)		

（論文内容の要旨）

The forefoot contains the transverse arch of the foot formed by the metatarsal heads. This arch helps in load transmission and shock absorption to allow forward propulsion. It centers the loads on the second metatarsal and foot pathologies occur when loads are distributed unevenly. Hallux valgus (HV), which is the lateral shift of the hallux and the medial shift of the first metatarsal, is the most common deformity in the forefoot. It affects quality of life and it is accompanied by forefoot pain. Forefoot pain is not fully understood and is affected by several stimuli; therefore, a detailed and accurate examination of the forefoot biomechanics is advised. We hypothesized that the feet with HV and those with pain have higher arches and more force on the 1MTH, and that there is a relation to the structure between HV and pain.

We recruited 68 women, who consented on participating in this study, during a healthcare event and their right and left feet were assessed. Exclusion criteria were past surgeries in the limbs, injuries in the limb in the last year, dependence, inability to complete the tests alone and feet with pain but without HV, keeping 105 feet to be analyzed in this study. Pain in the forefoot was self-reported using a questionnaire and hallux valgus angle (HVA) was measured using a finger goniometer in weight-bearing. These feet were then divided into two main groups: 1) normal feet (NORM) and 2) HV feet (HVG); and further two subgroups: 1) HV without forefoot pain (HV Pain(-)) and 2) HV with forefoot pain (HV Pain(+)). We compared these two sets of groups by testing 1) the transverse arch structure (transverse arch height (TAH), sesamoid rotation angle (SRA), heights of the metatarsal heads (MTH)), by using a weight-bearing ultrasound, and also 2) the force underneath each MTH, by using precise force sensors. We further tested whether these parameters were related to HVA or with forefoot pain. The weight-bearing ultrasound permits to have a coronal view of each MTH and the sesamoids. The precise force sensors permit to measure force under each MTH separately as these sensors are stuck to direct skin after palpation. The measurements were done in three position: sitting, quiet standing and 90% weight shift (90%WS) on the tested foot (simulation of terminal stance phase).

In HVG compared to NORM, our main results were significantly higher TAH in all positions; significantly higher SRA in sitting, significantly lower medial sesamoid (MS) height in all positions and significantly higher lateral sesamoid (LS) height in 90%WS position. Meanwhile, in HV Pain(+) compared to HV Pain(-), only LS height was significantly higher in 90%WS. Force under the MTH were trends of higher forces on

the medial aspect of the forefoot HVG and HV Pain(+) in standing and 90%WS. Furthermore, TAH, MS height and force under 4MTH were associated with HVA; while, LS height and force under 5MTH were associated with pain.

In HV, the TAH and SRA are increased due to the rotation of the sesamoids. LS enters 2MTH's space causing it to elevate because of lack of space. This latter event may be the cause of forefoot pain in HV Pain(+), where LS height is increased. As for the force, its tendency to be higher on the medial aspect of the foot, and lower on the lateral aspect of the foot may be caused by the lack of the 1st ray to transmit forces to the lesser toes, as in normal dynamics. The forces are repeatedly focused on the medial side, causing pain on the long term.

From this study we understand the importance of assessing the structure of the transverse arch, which is related to HVA and forefoot pain in HV. Future studies may assess the effectiveness of arch flexibility and strengthening methods.

（続紙　２　）

（論文審査の結果の要旨）

前足部は中足骨の骨頭部によって横アーチを形成しており、荷重時の圧伝達や衝撃吸収に寄与している。外反母趾と前足部の横アーチが関与している事は知られているが、痛みに対してどのように関連しているかは知られていない。そこで本研究においては荷重時の超音波画像と力学的感圧センサーを用いて、外反母趾の痛みと前足部の横アーチとの関連を明らかにする事を目的とした。

地域在住の68名の女性を対象に、外反母趾の有無によって2群に、また外反母趾群では前足部の痛みの有無によってさらに2群に分けた。それぞれの群において座位、立位、90%荷重時の横アーチ構造を超音波診断装置、荷重時の中足部圧を感圧センサーを用いて評価した。横アーチ構造の変化については超音波診断装置で取得した画像から、足底部から中足骨までの高さ(中足骨高)、足底部から内側、外側の種子骨底面までの高さと種子骨の回旋角度(種子骨回旋角度)を測定した。

この結果、外反母趾群は正常群と比較して、いずれの荷重時においても高い中足骨高と内側種子骨高を示した。痛みを有する外反母趾群では外側の種子骨高が高く、内側の足部圧が上昇する傾向を示した。これらの結果は、外反母趾において荷重時の横アーチ構造の変化と痛みの関連を明らかにする上で重要な知見を与えている。

したがって、本論文は博士（人間健康科学）の学位論文として価値あるものと認める。

なお、本学位授与申請者は、令和２年１月１０日実施の論文内容とそれに関連した試問を受け、合格と認められた。

要旨公表可能日：　　年　　月　　日以降